EEG Measure

Course Instructor

Dr. Annushree Bablani

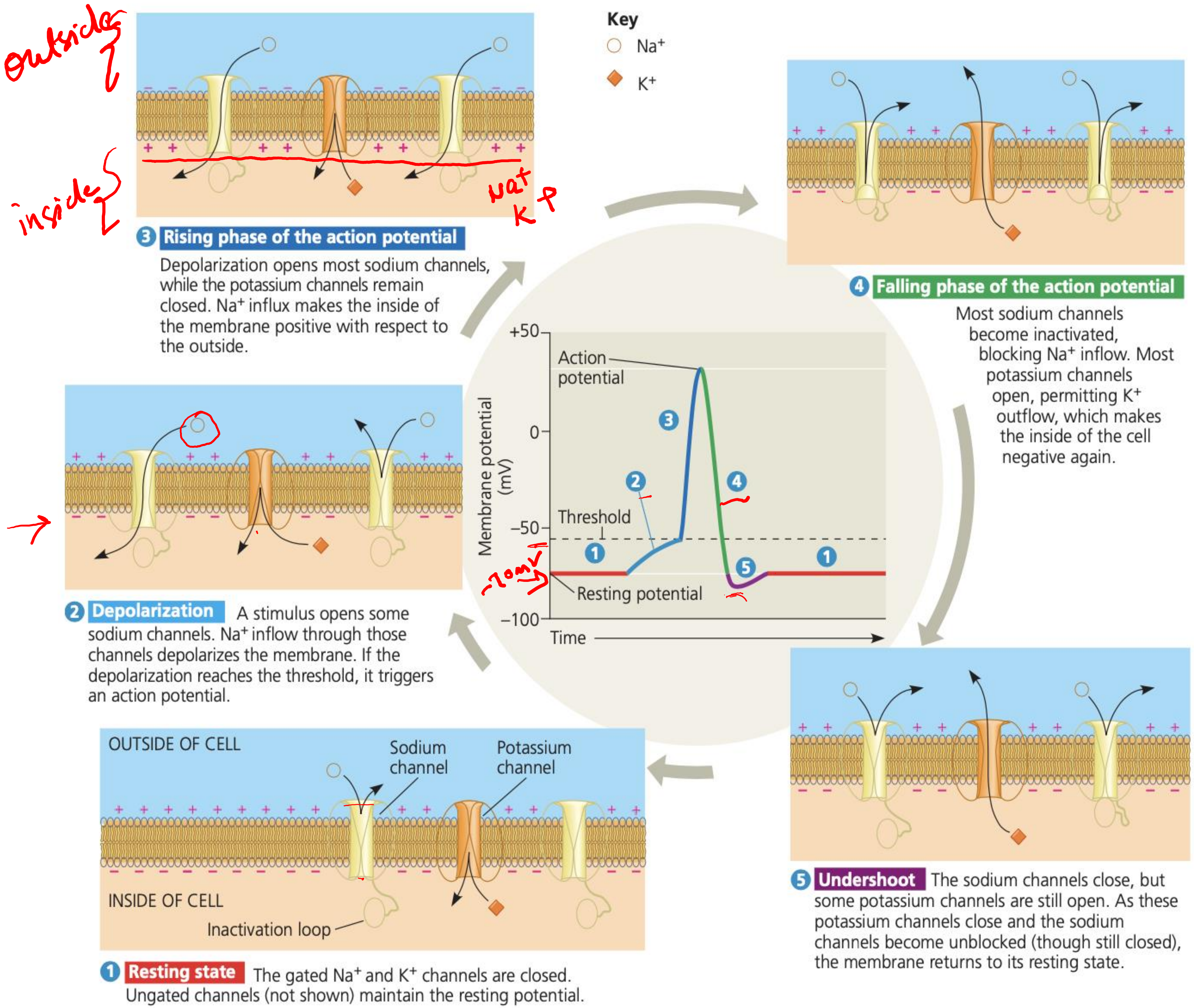
Acknowledgments: Dr Sreeja SR

REVISIT

- **Neurons** are nerve cells that transfer information within the body
- Neurons use two types of signals to communicate: electrical signals (long-distance) and chemical signals (short-distance)
- Nervous systems process information in three stages: sensory input, integration, and motor output

Hyperpolarization and Depolarization

- Changes in membrane potential occur because neurons contain **gated ion channels** that open or close in response to stimuli.
- When gated K^+ channels open, K^+ diffuses out, making the inside of the cell more negative. This is **hyperpolarization**, a reduction in magnitude of the membrane potential.
- Opening other types of ion channels triggers a **depolarization**, an increase in the magnitude of the membrane potential. For example, depolarization occurs if gated Na^+ channels open and Na^+ diffuses into the cell.
- **Graded potentials** are changes in polarization where the magnitude of the change varies with the strength of the stimulus.
- If a depolarization shifts the membrane potential sufficiently, it results in a massive change in membrane voltage called an **action potential.**


Key
Na+
K+
outside
inside
Na+
K+
3 Rising phase of the action potential
Depolarization opens most sodium channels, while the potassium channels remain closed. Na+ influx makes the inside of the membrane positive with respect to the outside.
4 Falling phase of the action potential
Most sodium channels become inactivated, blocking Na+ inflow. Most potassium channels open, permitting K+ outflow, which makes the inside of the cell negative again.
+50
0
−50
−100
Membrane potential (mV)
Action potential
Threshold
Resting potential
-70mV
Time
2 Depolarization A stimulus opens some sodium channels. Na+ inflow through those channels depolarizes the membrane. If the depolarization reaches the threshold, it triggers an action potential.
OUTSIDE OF CELL
Sodium channel
Potassium channel
INSIDE OF CELL
Inactivation loop
1 Resting state The gated Na+ and K+ channels are closed. Ungated channels (not shown) maintain the resting potential.
5 Undershoot The sodium channels close, but some potassium channels are still open. As these potassium channels close and the sodium channels become unblocked (though still closed), the membrane returns to its resting state.

Generation of Postsynaptic Potentials

- Direct synaptic transmission involves binding of neurotransmitters to **ligand-gated ion channels** in the postsynaptic cell.
- Neurotransmitter binding causes ion channels to open, generating a postsynaptic potential.
- Postsynaptic potentials fall into two categories
    - **Excitatory postsynaptic potentials (EPSPs)** are depolarizations that bring the membrane potential toward threshold.
    - **Inhibitory postsynaptic potentials (IPSPs)** are hyperpolarizations that move the membrane potential farther from threshold.

What are we measuring with EEG?

What does the EEG record?

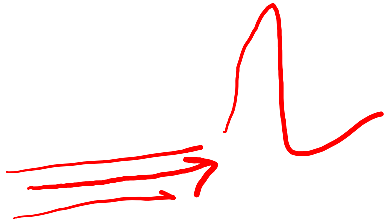
Mainly NOISE!!

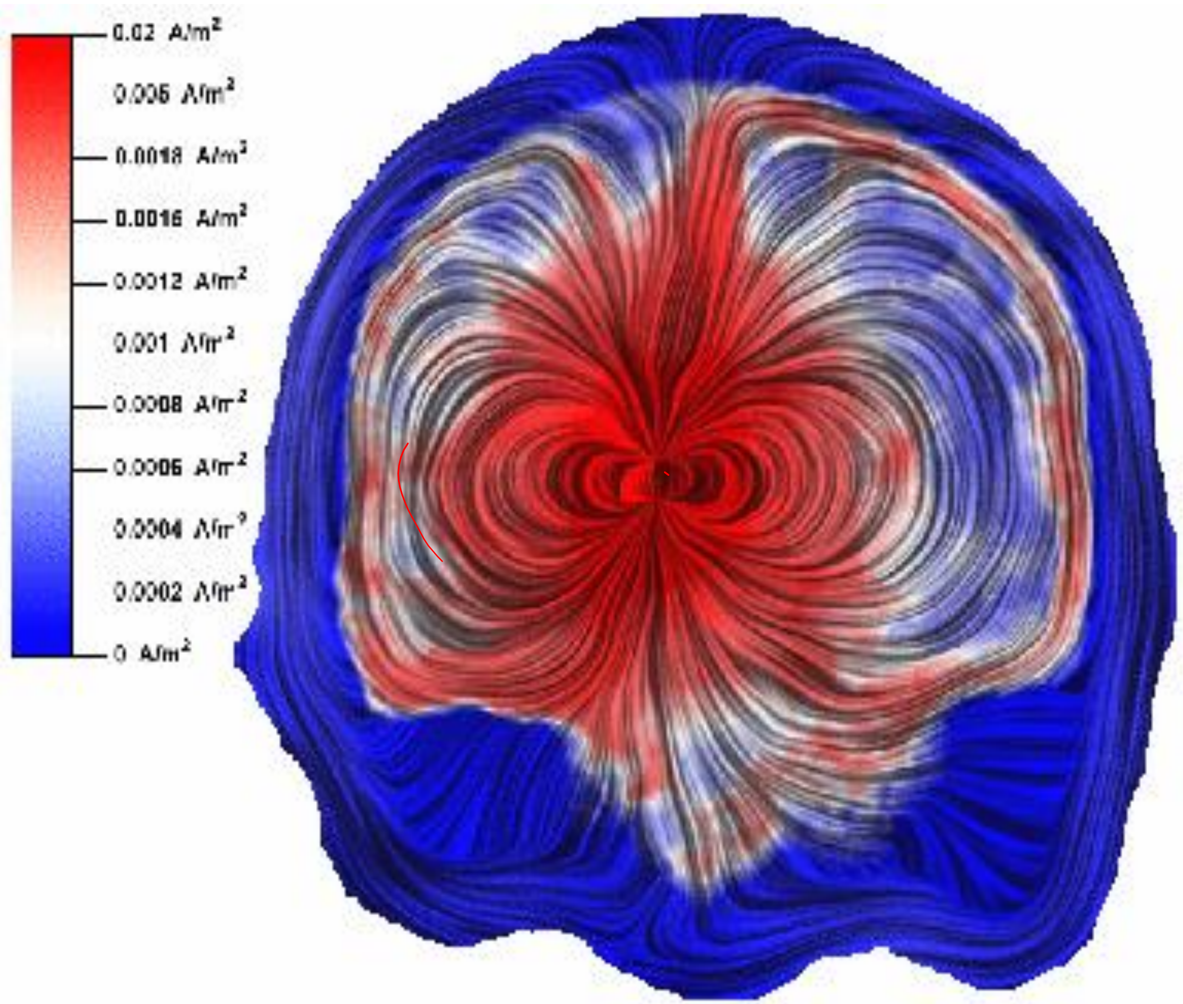
Volume Conduction

EEG directly measures the neural activity.

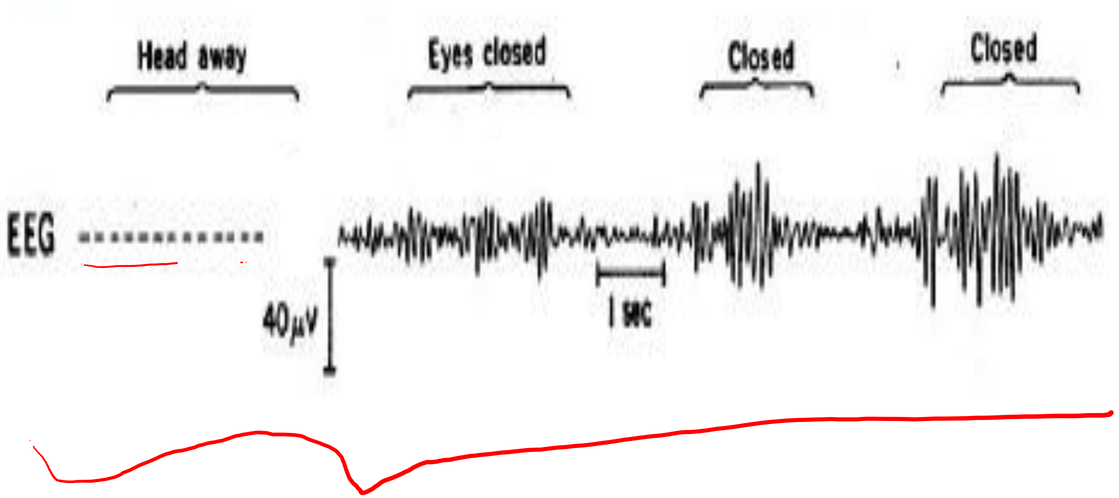
What kind of neuronal activity?

- **Action potentials**
- **Postsynaptic potentials**



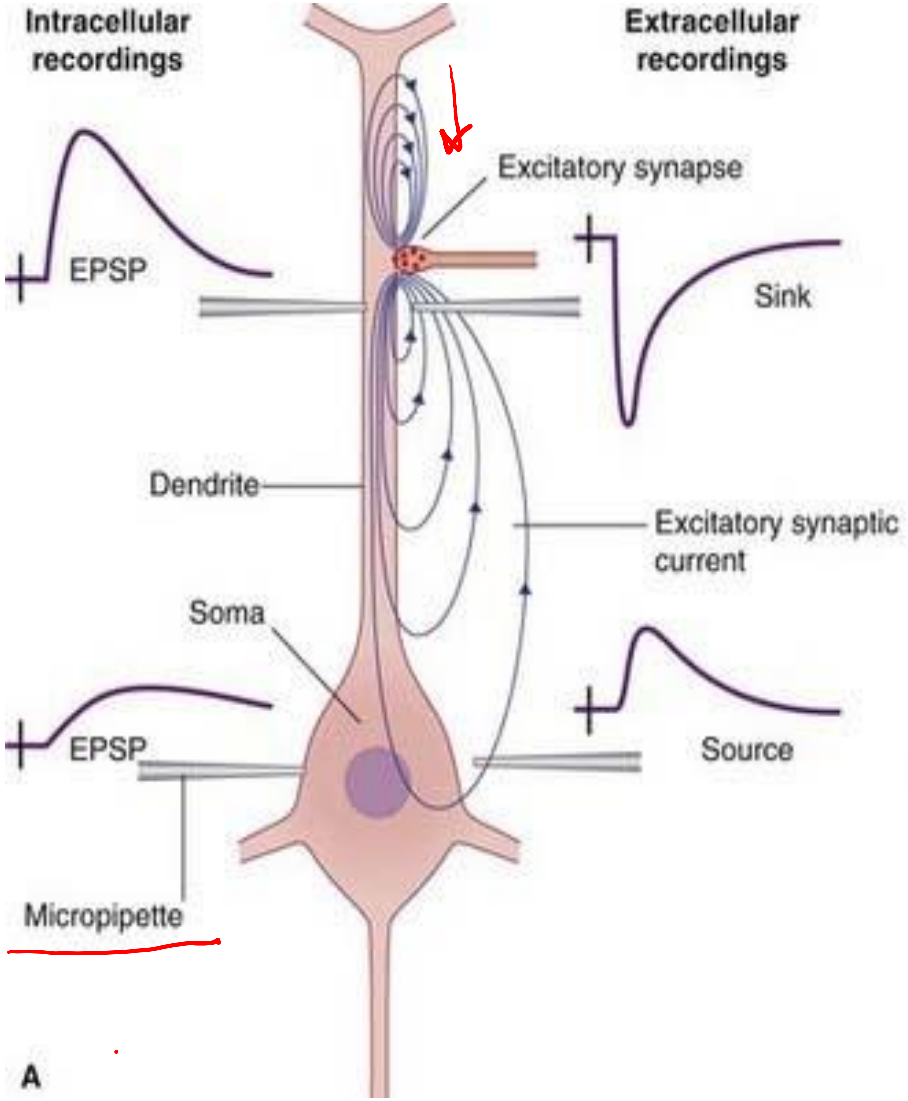


EEG measures the underlying neural currents



- **EEG**: Measures differences in electric potential at the scalp.
- Non-invasive, cover the whole head, and have very high temporal resolution.

Neural basis of the EEG

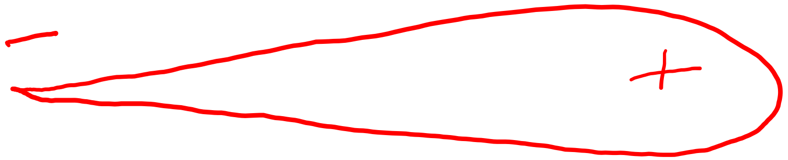


https://clinicalgate.com/electroencephalography/

When an EPSP is generated in the dendrites of a neuron an extracellular electrode detects a negative voltage difference, resulting from Na^+ currents flowing inside the neuron's cytoplasm.

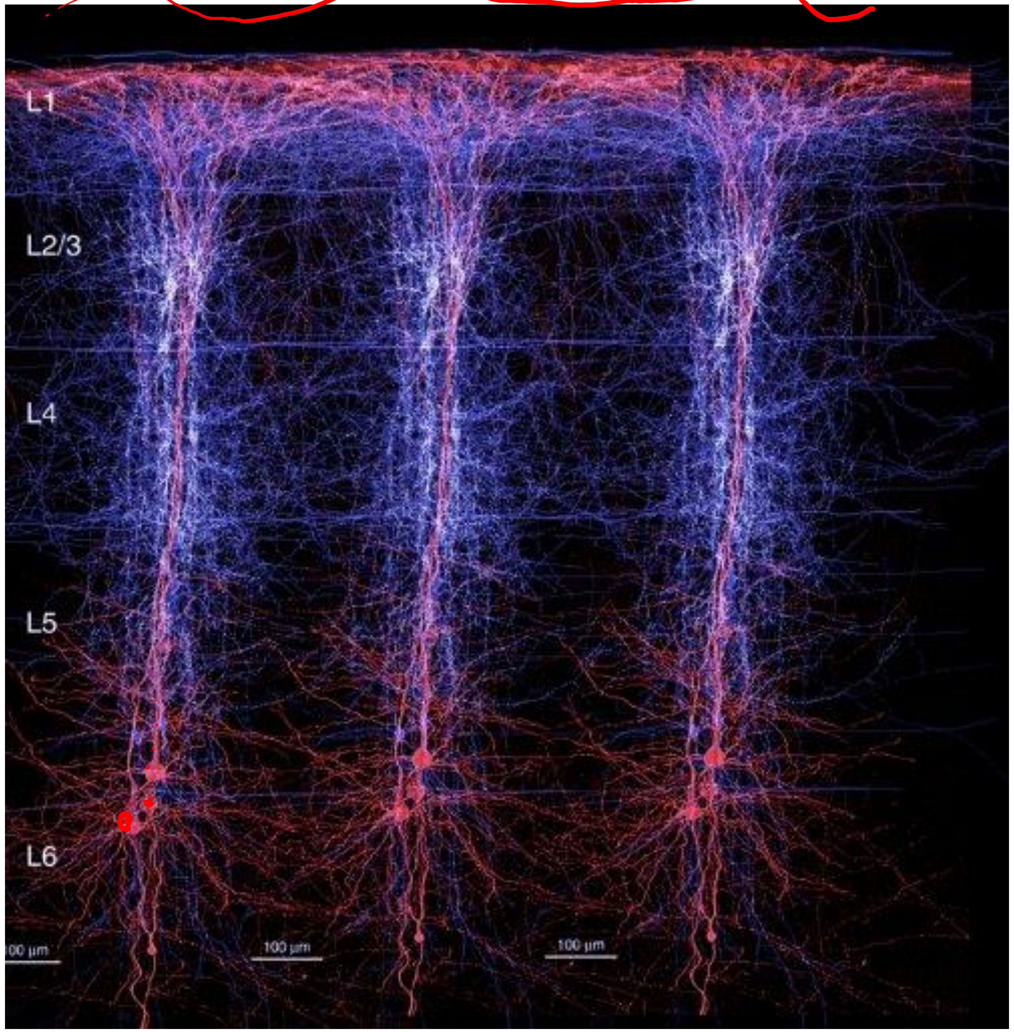
The current completes a loop further away the excitatory input (Na^+ flows outside the cell), being recorded as a positive voltage difference by an extracellular electrode.

This process can last hundreds of milliseconds.



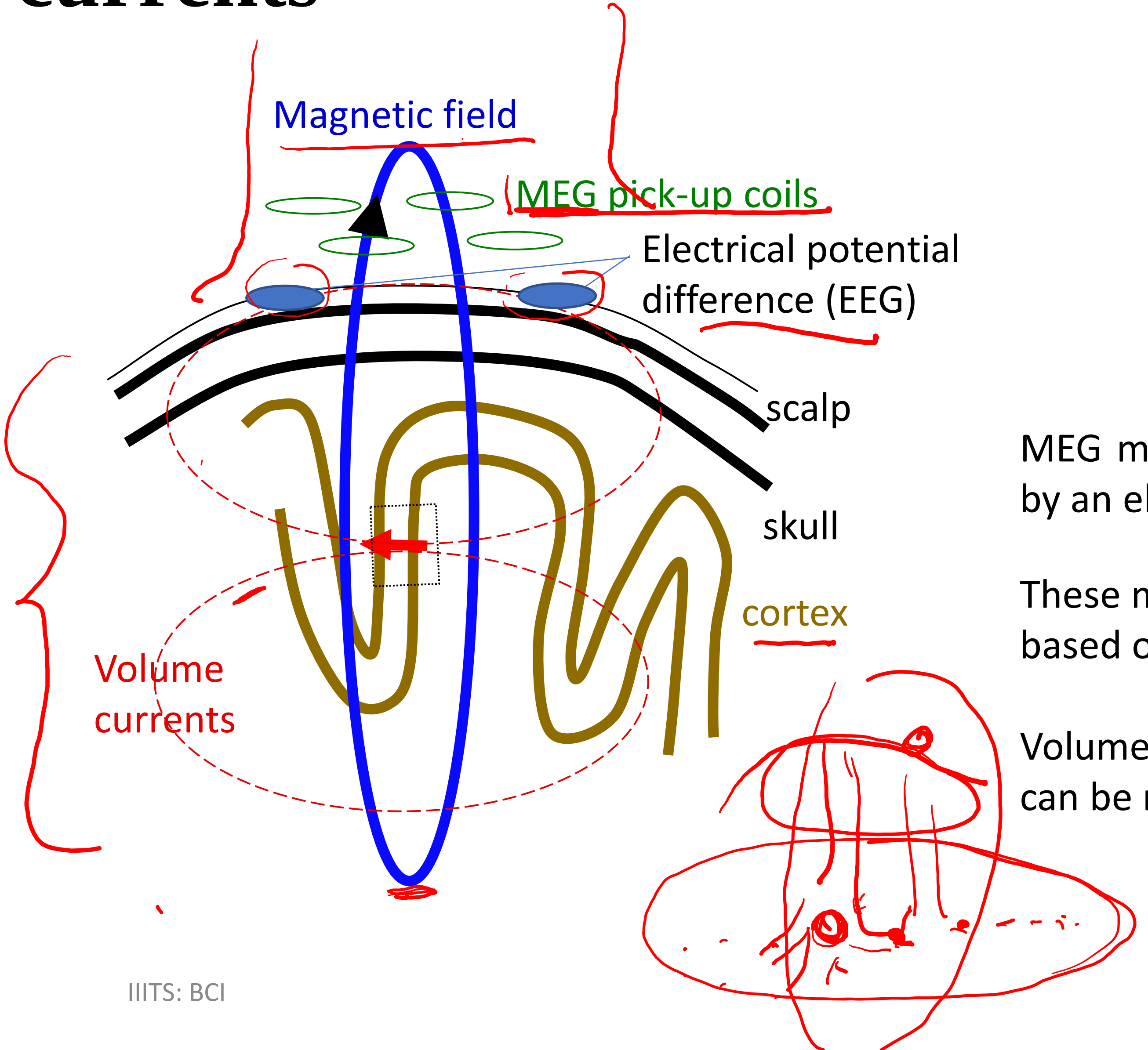
From single neuron to neural population

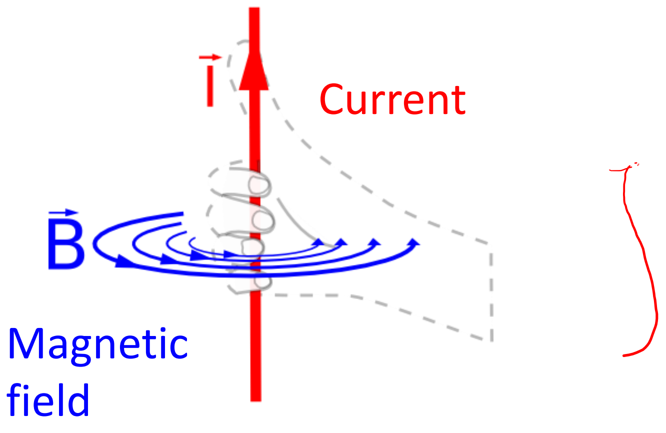
- The geometry of the neuron must give rise to a net dipole current to contribute to the EEG signal.
- A large number of neurons have to be active simultaneously to generate a measurable EEG signal.
- Pyramidal neurons are spatially aligned and perpendicular to the cortical surface.
- Thus, EEG represents mainly the postsynaptic potentials of pyramidal neurons close to the recording electrode.
- The electrical activity from deeper generators gets dispersed and attenuated by volume conduction effects.



BBP/EPFL

Primary intracellular currents give rise to volume currents





MEG measures the changes in the magnetic field generated by an electric current (Sarvas 1987, Hämäläinen 1993)

These magnetic fields are mainly induced by primary currents based on excitatory activity (Okada et al. 1997)

Volume currents yield potential differences on the scalp that can be measured by EEG.

- The connection between electricity and magnetism was first discovered by Hans Christian Orsted in 1819.
- He demonstrated that a magnetic compass needle was affected by a current passing through a circuit.
- An electrical dipole is always surrounded by a corresponding magnetic field.
- The polarity of the field is determined by the direction of the current.

History

1929: Hans Berger developed the electroencephalography (=graphic representation of the difference in voltage between two different cerebral locations plotted over time) following the studies of Richard Caton in non-human animal species.

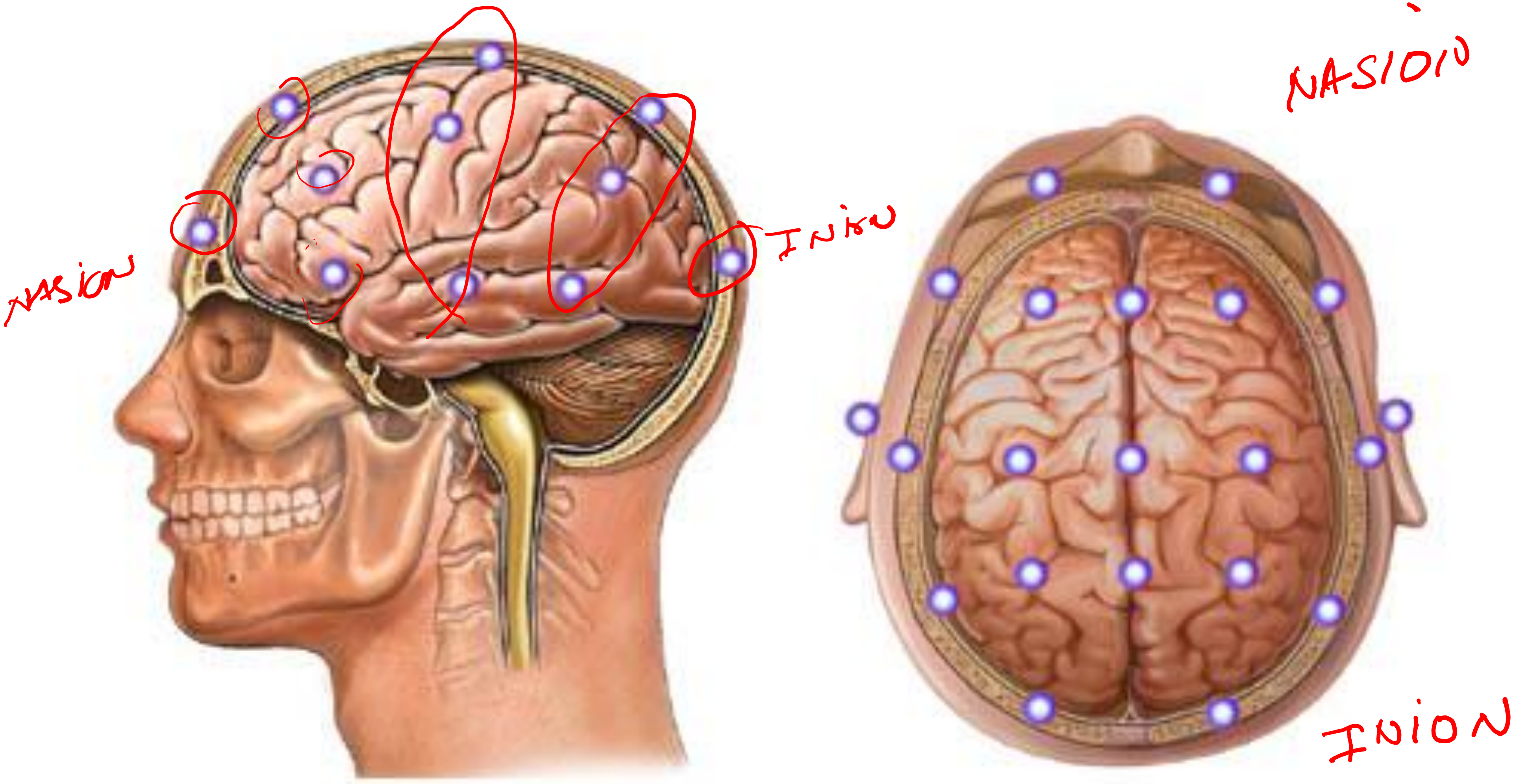
He described the human alpha and beta rhythms.

8-13 Hz

Berger waves

High density EEG recording

Electrode placing locations in EEG



Elect… ation in EEG

The names of the electrode sites use alphabetical abbreviations that identify the lobe or area of the brain to which each electrode refers:

F = frontal

Fp = frontopolar

T = temporal

C = central

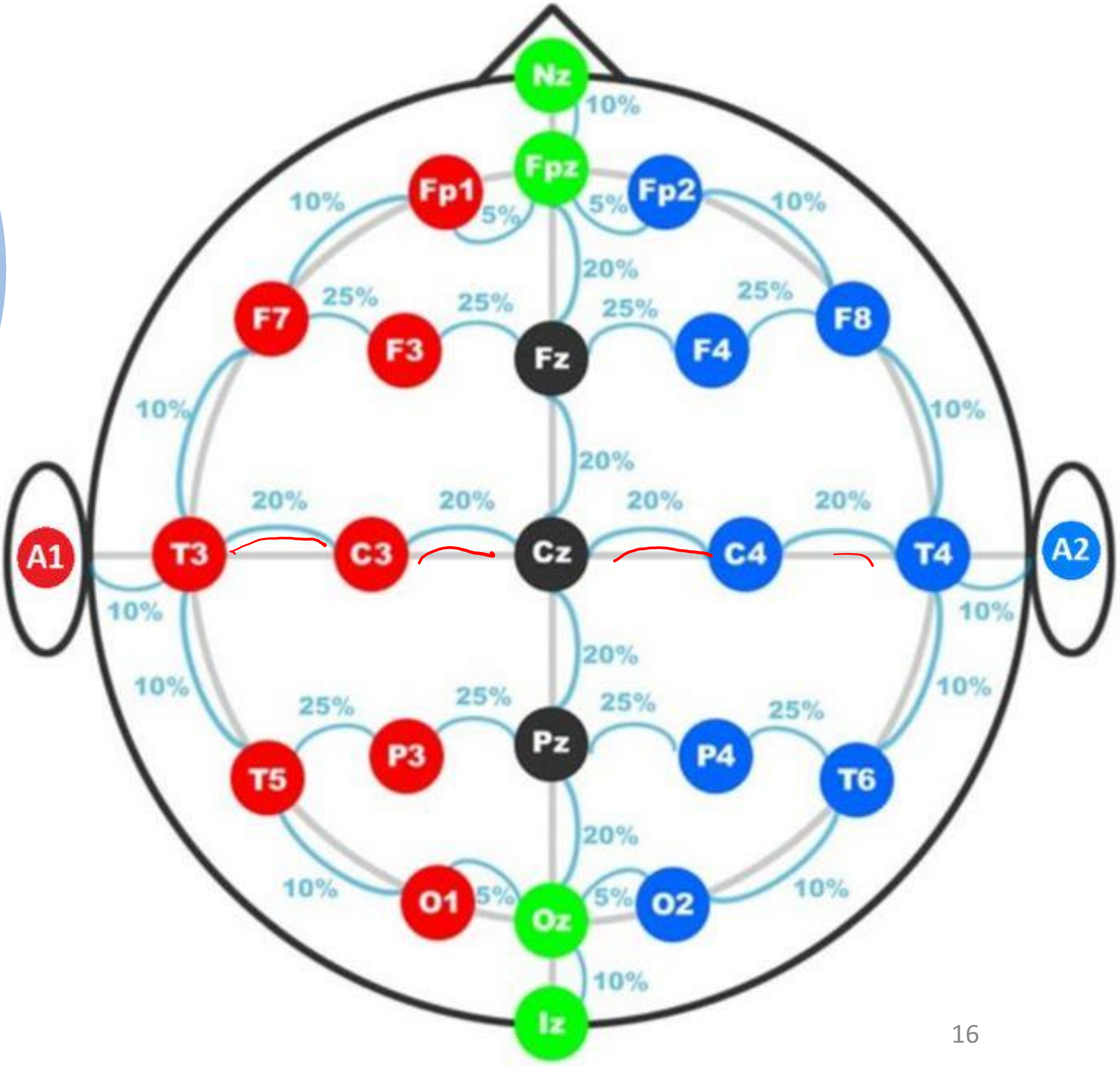
P = parietal

O = occipital

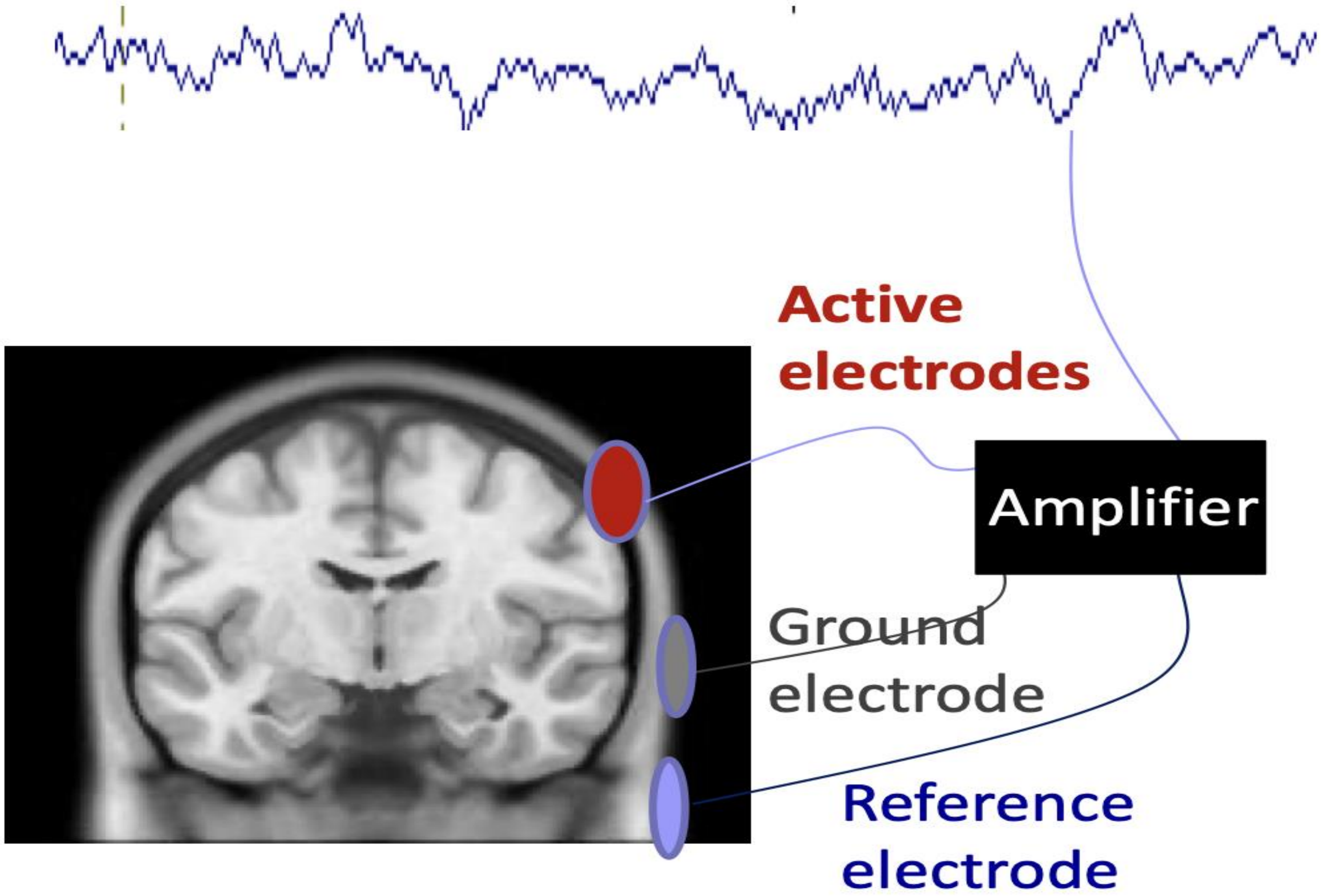
A = auricular (ear electrode)

"z" refers to an electrode placed on the mid-line

- **Even numbers** denote the right side of the head and **odd numbers** the left side of the head.



Measuring EEG…



Measuring EEG…

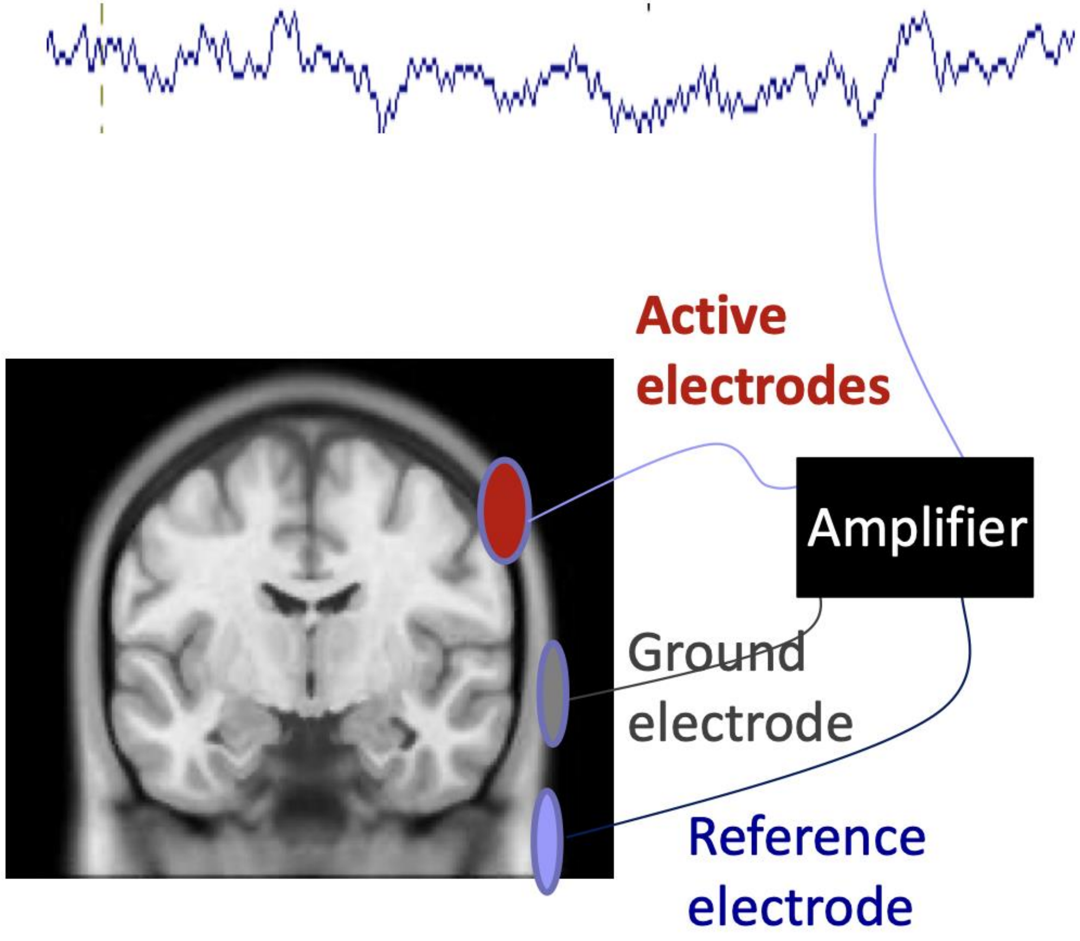
Electric fields affecting measurements:

1. Static electric current
2. Electric noise
3. Brain activity

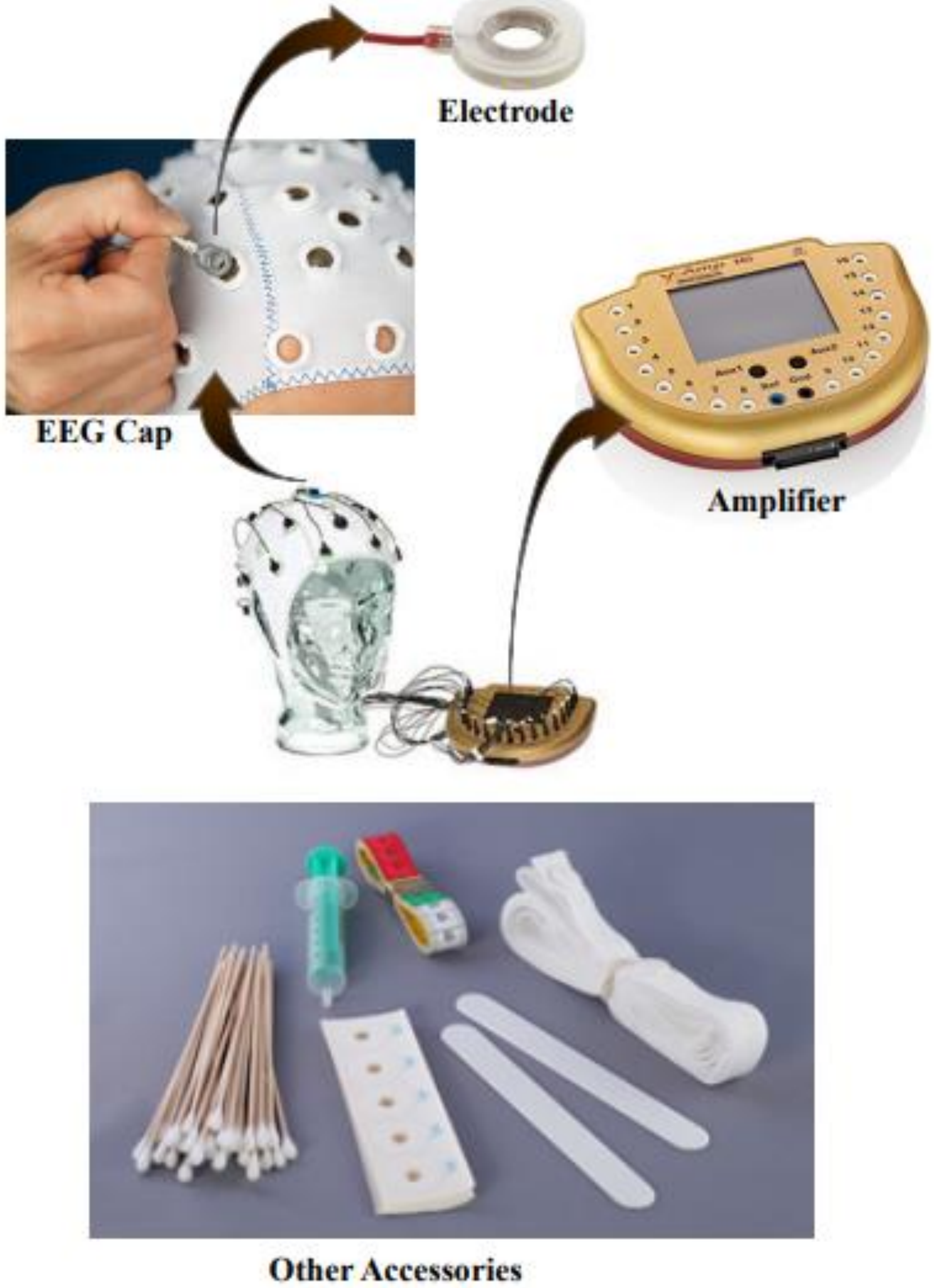
Ground = difference between the participant and the amplifier

➔Subtracted from the active and reference electrode activity: A-G, R-G

➔is the reference point in an electrical circuit from which voltages are measured, a common return path for electric current, or a direct physical connection to the Earth.

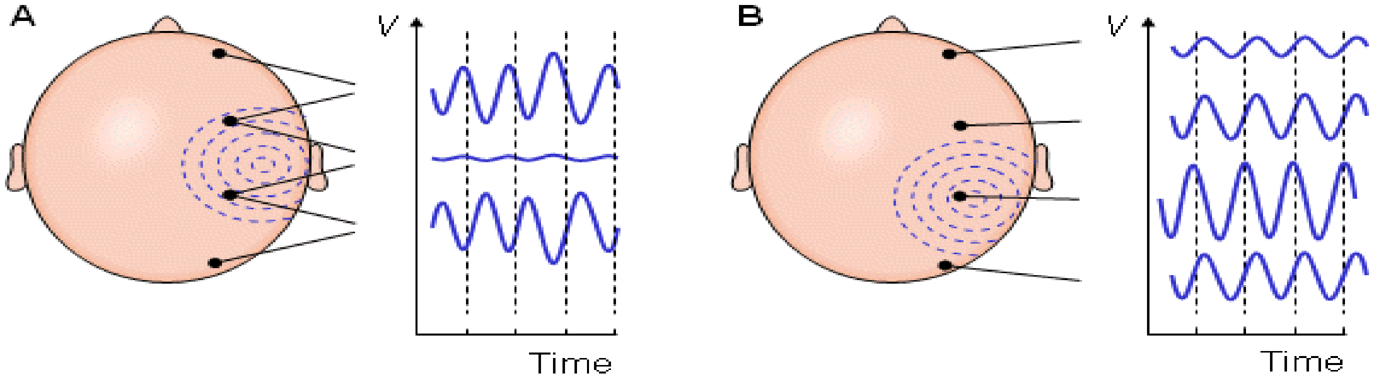


An EEG Device



Measuring EEG…

- EEG records potential differences at the scalp using a set of electrodes and a reference.
- The ground electrode is important to eliminate noise from the amplifier circuit.
- The representation of the EEG channels is referred to as a montage
  - Unipolar/Referential ⇒ potential difference between electrode and designated reference
  - Bipolar ⇒ represents difference between adjacent electrodes (e.g. ECG, EOG)
- Potential differences are then amplified and filtered



Thank you!!